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THE ANIMAL MIND AND ITS SIGNIFICANCE FOR BIOLOGY.

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It cannot be denied that some explanation is required of a biologist who chooses as a subject for a lecture a theme which could, from nearly every point of view; clearly be treated better by a professional psychologist than by a biologist. Nevertheless, granting this, as we certainly must, there still seems room for its treatment by a biologist to biologists, and, therefore, it is, perhaps, not an unsuitable subject for me to choose for your Fletcher Memorial Lecture, which you have done me the honour of inviting me to deliver this year.

The history of science shows two opposite tendencies. Including at first the whole range of nature, natural science in the not so distant past was thought to be a proper subject for a University Chair. But the mere growth of knowledge made it necessary to subdivide the field for purposes of practical study. Later still, as knowledge increases still further, the boundaries of these subdivisions spread out till they overlap again, and regions are established which have to use the discoveries and concepts of different branches of scientific discipline. Of recent years the region common to physics and chemistry has been very prominent. The common ground of biology and chemistry has grown enormously in the last generation. The contact between zoology and psychology is less well established. The fact that the vital processes, such as morphogenesis, or physiological regulation, have a physico-chemical aspect has been thoroughly appreciated for many years; that they may have a psychical aspect will be much less universally admitted, though it may be equally true.

There is another aspect of animal psychology, however, in which every biologist is bound to be professionally interested, and that is the evolutionary aspect. His conception of organic evolution is obviously incomplete if he ignores the evolution of mind. He will be lucky indeed if he arrives at a correct conception of the process and course of evolution if all consideration of the evolution of the most characteristic of all animal functions is left out of the picture.

It is convenient to begin by distinguishing the two main subdivisions of animal behaviour recognized by nearly all animal psychologists. Firstly, there is that type of behaviour which is determined by the innate organization of the animal, that is to say, reflex and instinctive behaviour. This type of behaviour is the outcome of the organization of the animal as this has been developed by the ordinary processes of embryonic development, often with post-embryonic maturation (as in the case of the sex instinct).

Secondly, we must recognize that type of behaviour which is determined by the animal's own previous experience; actions which the animal has learnt by experience to be appropriate to certain situations. This type of behaviour is intelligent behaviour. The bird builds its nest instinctively; a dog recognizes intelligently that the sound of the dinner bell means food.

Let us consider briefly the nature and relations of these two types of behaviour. Instincts are sometimes looked upon as compound reflexes, but McDougall has stressed the necessity for distinguishing sharply between these two modes of action. A reflex action is a reaction to a stimulus as such, without reference to the source of the stimulus. Instinctive action, however, is a reaction not merely to the stimulus itself, but to the object or situation which the stimulus means or signifies to the animal. Flash a bright light on to a dog's eye. It will blink—a reflex action to the stimulus itself. But if the image of a rabbit falls upon its retina, it will react, not merely to the stimulus of the optic nerve, but to the rabbit, which the stimulus signifies to the animal.

Thus, while the reflex act merely involves the touching off of a preformed mechanism, like putting a penny in an automatic machine, an instinctive act involves a striving towards a goal. Instinctive action, therefore, implies cognition and conation. Moreover, as McDougall also points out, the same instinctive action may employ different motor mechanisms on different occasions.

We know from our own experience that reflex action is not usually a conscious action. Instinctive action, on the other hand, is accompanied in our own case, and, therefore, presumably in the case of animals, by conscious experience of the type called emotion, according to McDougall's terminology. The operation of the instinct of escape is accompanied by the emotion of fear, and so on.

It seems clear that in order to be effective, only the simplest instinctive actions can be absolutely determined in every detail by the organization of the animal. Only the impulse to the action and the general course of the action can be thus determined, because the exact situation and, therefore, the exact means to be taken to attain the goal, can hardly ever be the same on any two occasions. Of course, the animal is guided in its movements by its sense organs, and by this means no doubt the spider is able to fix its web to the appropriate supports and shape the whole to the space at its disposal. The power to do that is included in the definition of the instinct. But animals in the performance of their instinctive acts are bound to come up against all sorts of minor obstacles, the appropriate way of dealing with which could not be part of the instinctive equipment of the animal, unless this included an enormous number of latent specific cognitive and conative dispositions which might not need to be brought into operation once in scores of generations. The way in which the details of the action can be suited to the minor features of the special case is a very simple one, but very important for the understanding of animal behaviour, and of mental evolution. It is the principle of trial and error.

It appears to be a fundamental attribute of animals to vary their previous activity (or inactivity) when they come into any situation which causes them pain or dissatisfaction—and this situation arises automatically when any animal receives a check when making for its instinctive goal. When this happens, the animal continues to make movements of the same general nature as those usually appropriate to attain the goal, but varies them in detail. Movements which fail to give it relief (in the case of the checked instinctive action, to bring it nearer its goal) are discontinued and others substituted, until one is found which gives the animal satisfaction; the stimulus to further change of activity no longer exists, and the present movement or state of rest is continued.

Thus it is that motile microscopic organisms, such as *Paramecium*, placed in a trough of water, one end of which is kept at an uncomfortably high temperature and the other end at normal temperature, will eventually congregate in the cool end. The uncomfortably high temperature causes them to dart about at random; those directions of movement which fail to give relief—i.e., fail to take the animal out of reach of the heat—are quickly discontinued, and the animal turns in a new direction. Sooner or later, it chances to move in a direction which takes it out of the hot area into the cool. There being now no incentive to further activity, the animal stays where it is. In this way, the animals gradually all find their way to the cool end.

There is nothing unfamiliar to us in this procedure. As long as we ourselves are comfortably situated, we feel no incentive to alter our condition, but when we experience discomfort or pain we get restless and try various ways of obtaining relief.

It is even possible to relate the frequency of change of action with the degree of discomfort or pain which evokes it. In one of my own experiments, water mites (*Eylais*) were placed in a horizontal glass tube about 60 cm. long, so arranged that it could be maintained at a constant temperature. In such a tube the animal swims up and down, sometimes reversing its direction after a short distance, sometimes after a long one. Each animal was left in the tube for an hour, and its track up and down the tube recorded. The average length of run between reversals of direction was as follows (compulsory turns at the ends of the tube not being counted). At a temperature of 6·5° C., the average run was 747 mm.; at 12·5°, 1,932 mm.; at 22·5°, 1,761 mm.; at 32°, 460 mm.; and at 37°, 72 mm.

It will be seen that at the "normal" temperatures, 12·5° and 22·5°, the reversals of direction are at much longer intervals than at higher or lower temperatures; and, indeed, one is led to the generalization that the rate of change of action is roughly proportional to the degree of injury and discomfort experienced during its performance. This seems to be the basis of the principle of trial and error.

This trial and error principle is the essential preliminary to intelligent behaviour. No intelligence is involved in the Paramecium's behaviour. That would appear if, in a second experiment with the same animals, their previous experience led them to turn away from the hot end and swim into the cool end of the trough, instead of chancing on the cool end by random movements—and we may be confident that this intelligence would not be displayed.

As an example of intelligence in this sense of learning by trial and error, let us take one of the earliest—if not the earliest—exact experiment on this subject.

Thorndike put a hungry cat in a cage, food being placed outside. The cage was provided with a sliding door to which was attached a string passing over a pulley and ending in a weight. The door was kept shut by a bolt, the withdrawal of which allowed the door to rise. To the bolt was fastened a string which, passing over a pulley and through the bars of the roof, ended in a ring hanging in the middle of the cage. Pulling on the ring would, therefore, cause the door to open.

The cat on being put into the cage tries to escape by biting and clawing at the bars and attempting to squeeze between them. Sooner or later it chances to claw or bite on the ring; it then finds itself at liberty. On successive occasions the cat gradually eliminates more and more of the preliminary useless efforts, and concentrates on the essential act of pulling the ring. One particular cat took the following times (in seconds) to pull the ring, and so gain its liberty, in twenty-four successive trials: 160, 30, 90, 60, 15, 28, 20, 30, 22, 11, 15, 20, 12, 10, 14, 10, 8, 8, 5, 10, 8, 6, 6, 7.

Biting the ring or pulling on it with its claw is, no doubt, an act of the general kind which a cat instinctively uses in efforts to escape from confinement. But animals will also learn to perform acts which can have no understandable relation to the result. For instance, in other experiments Thorndike opened the cage door himself whenever the cats licked themselves, and they soon learnt to do this immediately they were put into the cage. Similarly, a chicken learnt to free itself by preening its feathers.

The power of learning by experience (and, therefore, according to definition, intelligence) has been demonstrated in all classes of vertebrates and in many invertebrate phyla.

Passing over certain equivocal evidence in the case of the Protozoa, and fairly strong evidence for the earthworm (Yerkes), Garth and Mitchell (1926) may be said to have proved it in the case of a land snail. The enormous and specialized phylum of the Arthropoda has been much experimented upon from this point of view. In this phylum my own experiments (1927) have failed to produce any evidence of intelligence in water mites (Hydrachnidae). The apparatus employed was a Y-shaped trough, supported on a pedestal in a dish containing water. The depth of the water in the dish was so adjusted that the trough contained only sufficient water to allow the animal to struggle along in it, half swimming, half crawling. The animal was introduced into the base of the stem of the Y; by the right hand arm it could escape into the deep surrounding water; escape from the left arm was prevented by a piece of clear glass. In one out of many experiments, in which the penalty for entering the wrong arm was not only failure to escape from the confinement and shallow water, but also the reception of an electric shock, the animal failed to show any signs of learning even after 800 trials.

This inability to learn a simple right or left hand choice is in marked contrast to the powers of another Arthropod, the freshwater crayfish, which will master this task very easily. It seems possible to correlate this difference of intelligence with the modes of life of the two creatures. The crayfish leads a life where some power of profiting by experience must clearly be of value—it searches for its food, attacks other animals, and defends itself against its enemies.

Water mites feed on *Daphnia* or other small Crustacea, but they catch them in a manner which affords no apparent scope for intelligence. They are animals of ceaseless activity, swimming rapidly round and round, up and down the vessel in which they are contained. If a water mite (*Eylais*) is placed in a small vessel with a few Daphnias, it seems quite unconscious of their presence, even at a distance of a millimetre. But when in its tireless travelling it chances to collide with one, it makes a rapid movement to seize its prey. If successful, the Daphnia is killed and its juice is sucked; if the mite fails to hold the Daphnia it circles once or twice round the spot and by so doing may strike the Daphnia again. If not, it soon resumes its general random activity. That mites find their prey by chance collisions with them is also indicated by the following experiment. Mites were put singly into small cylindrical vessels, containing about 25 c.c. of water. Into one series of vessels, one Daphnia was placed; in a second series, two; in others, four, eight and sixteen respectively; and the time taken by the mite to catch one was noted. It was found that the time varied inversely as the number of Daphnias present. Thus the average time taken to catch a Daphnia when there were four present was approximately eighteen minutes; when eight were present, eleven minutes; and when there were sixteen, four minutes. Such a result could not have been obtained in the case of an animal tracking down its prey by its sense organs; it is apparent that ability to learn by experience could find little scope in such a process.

Many experimenters have demonstrated intelligence in the higher Crustacea and Insecta. I may perhaps again instance some experiments of my own on the Australian freshwater crayfish or yabby, *Parachaeraps bicarinatus* (unpublished data). The crayfish, placed in a box with two openings, will quickly learn always to escape by the right or left one, especially if the penalty for attempting the wrong one is not only failure to escape, but also an electric shock. On the other hand, I have never succeeded in getting them to form an association between an illuminated opening and an electric shock. If one of the two openings, irregularly or alternatively the right and left, is illuminated and at the same time electrified, they will not succeed—at least, not in 600 lessons—in learning to avoid this opening and escape by the unilluminated opening (or vice versa). One specimen which was given 440 lessons in such an apparatus, and failed completely to form any association between the light and the shock (or at any rate to regulate its movements thereby) was rested for three days at the end of the experiment (which had extended over 176 days). It was then tried again in the same apparatus, only this time there was no difference of illumination between the two exits, but the left hand opening was left permanently electrified and the right hand one free. (In the 440 trials of the first experiment, this animal had gone rather more often to the left than to the right opening.) The animal was given 80 trials at its new task, six a day. It made five errors in the first ten trials, four in the second ten, and only three in the remaining sixty.

While such experiments as these demonstrate the power of learning, they certainly suggest that it is very poorly developed. But laboratory experiments of this type can only demonstrate intelligence; they cannot measure it. It can hardly be doubted that animals will learn much more readily from the kind of experiences which they encounter in their natural modes of life. It seems extraordinary that a crayfish should learn so quickly by which of the two openings it has to escape from confinement, as long as that opening is always the same one, and yet shown no signs, even after 600 lessons, of learning that the attempt to escape through an illuminated opening is fruitless and attended by a painful sensation. But it may be that the crayfish, although (as can easily be proved) it sees the light, does not see it as part of the confinement-escape situation in the way that the experimenter does.

These experiments, in short, indicate a general capacity for learning the results of certain actions and movements. Obviously, very many of our own skilled actions have been acquired by this method of trial and error, though so much of this acquisition has come about gradually in our childhood that we are not conscious of the fact. A baby even learns how to put its finger in its mouth by trial and error. And, indeed, the play of young animals must result in the accumulation of great stores of experience in this way. The most intelligent of animals—the mammals—begin life with a considerable period during which they are supported and protected by their parents. Thus they have time to make innumerable little experiments and gain a great amount of experience of the results of all sorts of actions before they are called upon to use these actions in matters of life and death. An animal such as an insect which has to fend for itself from the moment it appears on the scene cannot afford to experiment. It has no time for play. Its instincts must be specialized, and its actions practically perfect the first time they are performed.

How can we pass from mere intelligent to rational behaviour? The cats in Thorndike's experiment may be said to perceive that pulling the ring was followed by liberty. But it is not necessary to suppose that they understand why pulling the ring set them free. A man placed in a similar situation, if he had no previous experience at all of mechanical devices, would probably in the first instance have to discover the method of opening the door by trial and error like the cat. He would simply pull and pull at everything he could get his hands on to. But having once pulled the ring and found the door slide up, he would never have to go through all the random efforts again. This is because he would examine the connection between the ring and door; as the result of his examination he would understand why pulling the ring set him at liberty. Moreover, if he were now put into another cage in which the door was operated by a lever instead of a ring and pulley, he would immediately set about looking for some indirect way of opening the door, and would soon discover the lever.

This would be *rational* behaviour. The man is reasoning. This seems to involve power of analysis and abstraction. The man's perception is not confined to a perception of the relation between his total action and the total result. He can see the relation between the various parts of his action and parts of the result, and can abstract certain general qualities or properties from the objects exhibiting them. According to McDougall, "the essential feature of reasoning is reaction to some aspect or quality of an object which marks it as appropriate for the purpose of the moment".

McDougall, though willing to allow to animals mental processes more like those of man than many psychologists are prepared to do, yet considers that it is difficult to point to behaviour that clearly implies reasoning in any animals lower than the apes. But it appears that the rudiments of this higher type of behaviour, even if not sufficiently developed to be called reasoning, can be traced further down than the apes. Thorndike found that cats trained to open a cage by pulling on a ring, when placed in a similar cage in which the door had to be opened by depressing a lever, learnt the new lesson more quickly than cats which had not the previous experience. McDougall relates how his dog learnt to open a puzzle box containing food. Before opening the lid (by depressing a lever) it was necessary to turn a horizontal button and push down a hinged board. It would perform these two preliminary operations, sometimes with its paw, and sometimes with its nose, and not always in the same order. Such behaviour seems to imply more than mere formation of associations between certain acts and the pleasure or pain of their results.

Do animals have ideas involving memory images of past experiences and the basing of plans for future action on them? Even the simplest forms of learning must involve memory, of course, but this does not necessarily mean that the animal has conscious recollection of its previous experiences. Let us take the example of an animal trained to escape from a box by the less brightly illuminated of two openings. Before training it escaped by either opening indifferently. But as a result of experiencing a painful electric shock whenever it went to the brighter opening, it now always chooses the other. This does not necessarily mean that it consciously remembers its previous experiences, and bases its action on this memory. It may be that it simply perceives the situation now differently from the way in which it did before its training. It now confronts the two openings with a dread of the bright opening, and possibly an attraction towards the darker one, without necessarily actually forming a memory image of its previous experiences.

A consideration of instinct indicates that the fact that the animal has come to dread the bright opening does not necessarily imply that it has conscious memory of its past experiences. We can compare the dread of the bright opening with the instinctive fear which many animals have of their natural enemies, or that nearly all higher vertebrates experience when they find their movements restricted; and here there is no question of memory, at any rate on the first occasion on which the fear is felt. And this suggests an extremely interesting problem, of which we can only conjecture the answer—what mental states accompany the first performance of an instinctive act? When a bird starts out to build its first nest, has it any idea of what the result of its activity will be? When an Ammophila wasp sets out to search for its first caterpillar, has it any idea of the appearance of the object of its search? Or when it has sighted one, has it any sort of expectation or premonition of what the rest of its action towards it is going to be?

McDougall believes that every instance of instinctive behaviour involves a knowing of some thing or object, a feeling in regard to it, and a striving towards or away from that object. He maintains that a bird has innate representation of the form of the nest which it is going to build.

Lloyd Morgan (1913) will allow less than this. He considers that at its first performance of an instinctive act the animal has only a vague feeling of interest in what is coming, rather than a perception (or "preperception") of the goal.

We can only guess at the mental state of the animal about to perform an instinctive act for the first time, not only because of our general ignorance of the mental states of the lower animals, but also because of our own lack of specialized instincts, involving the performance of long and complicated action; we can, therefore, draw little analogy from our own experiences. All our actions, except such simple instinctive ones as hitting a man when we are angry, or running away from danger, have been learnt, and we, therefore, have a memory image to act as goal for our activities. It is interesting to speculate on the different form that the science of psychology might have taken had human beings been endowed with even one complicated mode of instinctive action, involving a long series of actions like those of a solitary wasp stocking its nest with paralysed prey, or a bird building its nest.

Although it seems absurd to question the presence of anticipatory images where previous experience is involved, the consideration of instinct makes it more difficult to be sure that memory images are also present. But it is possible to produce experimental evidence upon this point. This is provided by the "delayed reaction" type of experiment. The animal is shown, by a light, from which of a number of compartments food can be obtained. At varying intervals after the extinction of the light the animal is released and the percentage of correct reactions is recorded. All mammals experimented on show the ability to choose the correct compartment after short intervals, but in some cases this depends upon the animal being allowed to maintain its orientation during the interval. On seeing the light (the association between light and food having been produced by preliminary training) the animal points its head in that direction, and on release it follows up that direction. Dogs and raccoons, however, do not require this aid. The evidence from the delayed reaction type of experiment is conveniently summarized by Washburn (1926).

In his fascinating book on the mentality of apes, Köhler gives many instances of the chimpanzee's ability to think of absent objects.

Consider this account of the behaviour of the solitary wasp, *Pompilus scelestus* (Peckhams, 1905). The wasp arrived at her nest with a spider, which proved too big to go into the hole. She pushed it out again, and carried it away to a place of safety among some clover blossoms. "She then washed and brushed herself neatly, and took several little walks, so that it was fully fifteen minutes before she began to enlarge her nest." During that interval she must have carried in her mind the idea of enlarging the nest to receive the spider.

However, we are getting into those regions of animal psychology which are furthest from the ordinary conceptions with which the zoologist works. Let us turn to those aspects which make closest contact with the general biologist.

What about the evolutionary aspect of the various grades of mental development which we find in the animal kingdom? Can the higher modes of mental life be derived by mere elaboration from the lower, or have we to postulate the appearance of something really new during the course of evolution? And the same problem occurs lower down. Are vital processes, such as embryonic development, of the same nature, fundamentally, as the behaviour of the organism as a whole in relation to its external environment, having, therefore, a psychical as well as a physical aspect? A full consideration of the second point would lead us very far into a discussion of the relation of the three great categories, inorganic processes, vital processes and conscious behaviour, and it would clearly be impossible to tack on such a discussion to the end of an evening's lecture. But it is worth recalling that many psychologists see no difficulty in uniting the last two categories. To quote McDougall again, "according to this view, then, not only conscious thinking, but also morphogenesis, heredity and evolution are psycho-physical processes" (1911).

It is easier to relate vital processes to instinctive than to intelligent behaviour. No valid evidence seems to be forthcoming that learning by experience occurs in vital processes. It is clear, of course, that these may adapt themselves to circumstances—as in the development of a partial embryo into a complete adult, or the development of appropriate buttresses in bones subjected to unusual stresses. Roux, indeed, distinguished two phases even in normal development. A first stage in which organs develop irrespective of functioning, and a second in which they complete their development in response to functioning. But there is no valid evidence to show that such adaptations occur more readily or more perfectly as a result of experience; that is to say, as a consequence of the discovery, by trial and error, that certain modes of growth gave more favourable results than others.

The result (as distinguished from the process) of learning by experience is a disposition to act in a certain manner when confronted with a certain object or situation; and once it has been formed, a learnt disposition seems to differ in no essential way from an innate disposition or instinct, except that it is usually less enduring. Are we then to suppose that instincts are the result of learning in past generations? This is, on the face of it, such a plausible way of accounting for specific instincts that psychologists have always tended to a belief in Lamarckian inheritance. McDougall's well-known experiment (still in progress) on inheritance of training in rats would seem to afford support to this view. It will be recalled that he trained rats to escape from a tank of water by the less brightly illuminated of two exits, and found a progressive decline in the average number of repetitions required to learn the lesson as the number of generations of training increased (McDougall, 1930). It would be unsafe to build any superstructure of theory on the result of his experiment before it has been repeated and confirmed, but, taken at its face value, the result of this experiment certainly seems to be in accord with the ideas of those who look upon instincts as inherited habits.

There are, however, very serious difficulties in the way of accepting such a theory as a general explanation of the relation between innate and learnt dispositions. There seem to be many instincts for which such an origin could not be postulated; for instance, actions which are performed only once in a life-time (such as cocoon-spinning in insects) and often after the germ cells are already cut off from organic connection with the body (many cases of copulation and oviposition).

Nor is it easy to conceive how increased facility in forming a specific mental disposition by association between certain actions and the consequent pleasure or pain could eventually result in its formation by the cell differentiations and cell movements which constitute embryonic development. This difficulty (inherent in all Lamarckian explanations) is surmounted by McDougall in a manner which few biologists would have the courage to suggest. He suggests (1911) that the structure of the germplasm may not be the only link between generations, but that there may be an enduring psychic existent of which the lives of individual organisms are but successive manifestations.

Whatever view one may hold as to their genetic relations, the fact that mental dispositions may be innate or formed as the result of experience is of the deepest significance to biological theory.

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